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(54) Valve drive device of an internal combustion engine

(57) Valve drive device of an internal combustion engine for operating at least one of intake and/or exhaust valves by at least one cam shaft, with a rocker arm unit having rocker arms being in mutual contact and at least one of the rocker shafts is displaceable to change the a timing and lift operation of said valve.

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Description

[0001] This invention relates to a valve drive device of an internal combustion engine, in particular a four-stroke cycle engine. The valves of said device are opened and closed as the lifts of cams formed on a rotary-driven camshaft are transmitted through rocker arms to the valves.

[0002] Exchanges of gasses in cylinders in the four-stroke cycle engine are performed as intake and exhaust ports communicating with the combustion chamber are opened and closed with intake and exhaust valves respectively according to appropriate timing.

[0003] In a four-stroke cycle engine, it is necessary to change one or both of the lift amount and opening-closing timing of at least one of intake and exhaust valves between high and low speed operations for achieving a high charging efficiency in high speed operation by accelerating the flow of intake or exhaust gas and for improving in low speed operation fuel economy and emission characteristic by securing a high combustion efficiency.

[0004] Therefore, a variable valve lift mechanism has been proposed and put to practical use, in which a cam for high speed and a cam for low speed are provided and the valve lift amount is changed between high speed and low speed operations by selectively making and breaking connection between rocker arms and cams by means of switching means.

[0005] A variable valve timing device has also been proposed and put to practical use, in which the valve opening-closing timing is changed between high speed and low speed operations by changing the rotation angle of the camshaft relative to the rotation angle of the crankshaft.

[0006] However, the variable valve lift mechanism of the prior art requires a plural number of cams and switching means for each cylinder. As a result, the constitution is complicated, the cost increases, and the valve lift amount cannot be changed continuously.

[0007] The variable valve timing device also has problems: since it is driven with hydraulic pressure, it requires complicated hydraulic circuit and hydraulic pressure control, and the variable range of the valve timing is insufficient.

[0008] It is an objective of the present invention to provide a valve drive device for an internal combustion engine providing a high engine performance and having a simple construction.

[0009] According to a first aspect of this invention said objective is solved by a valve drive device of an internal combustion engine in particular a four-stroke cycle engine, for operating at least one of intake and/or exhaust valves by at least one cam shaft, with a rocker arm unit for transmitting a controlling movement to said valve, said rocker arm unit comprises first and second rocker arms supported on first and second rocker shafts, respectively, wherein said first and second rocker arms are in mutual contact and at least one of the rocker shafts is displaceable.

[0010] According to a second aspect of this invention said objective is solved by a valve drive device of an internal combustion engine in particular a four-stroke cycle engine, for operating at least one of intake and/or exhaust valves by a rotating cam associated with said valve, with a rocker arm unit interposed between said cam and said valve for transmitting a controlling movement to said valve and for adjusting both a degree of lift and a lift curve of said valve so as to change the a timing and lift operation of said valve.

[0011] Preferably, the first rocker shaft is fixed and the first rocker arm supported on the said first rocker shaft is in contact with said valve, and the second rocker shaft is displaceable and the second rocker arm supported on the said second rocker shaft is in contact with a cam of the cam shaft and with the first rocker arm, wherein a contact point of the first rocker arm with the second rocker arm is moveable on the first rocker arm in accordance with the displacement of the second rocker shaft.

[0012] An arm means is attached to the first rocker shaft, and the second rocker shaft is supported at said arm means. Said arm means is pivotably about the first rocker shaft, wherein a drive means is provided for pivoting said arm means.

[0013] According to a preferred embodiment a pivoting angle of the arm means is controllable by a controlling unit in accordance with engine operating conditions.

[0014] It is further preferred that, the second rocker arm comprises a roller, and said roller is rotatable and in contact with the cam of the cam shaft. Said roller is rotatably supported on a roller shaft, and said roller shaft is in contact with the first rocker arm.

[0015] According to a preferred embodiment the second rocker arm comprises a pair of rocker arm portions spaced from each other and bridged by a roller shaft at distal ends thereof, and said first rocker arm comprises a pair of rocker arm portions being in contact with a pair of valves, respectively. A roller is provided between the rocker arm portions of the first rocker arm and rotatably supported on the roller shaft, wherein parts of the roller shaft are exposed out of the roller and in contact with the rocker arm portions of the first rocker arm.

[0016] A pair of arm means spaced from each other is attached to the first rocker shaft, and the second rocker shaft comprises a pair of shaft sections supported at said pair of arm means, respectively, said pair of shaft sections of the second rocker shaft supporting the pair of rocker arm portions, respectively, wherein a free space is provided between said pair of arm means and the pair of rocker arm portions to allow the cam of the cam shaft to rotate within said free space.

[0017] The rocker arm portions of the first rocker arm are connected by a boss portion rotatably supported on said first rocker shaft.

[0018] According to a preferred embodiment said first rocker shaft and said second rocker shaft are parallel

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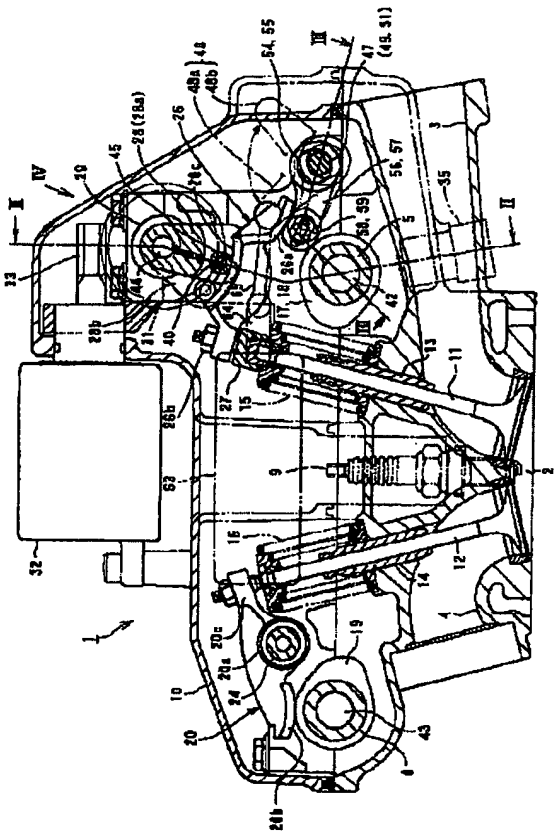

ABSTRACT : PROBLEM TO BE SOLVED: To improve engine characteristics, fuel consumption efficiency, durability, a high rotational follow-up property, etc.

SOLUTION: This valve system of the 4-cycle engine is provided with a fulcrum member 28 to rotate around a fulcrum revolution shaft 29, and a first actuator 32 to rotate this fulcrum member 28. A tip of the fulcrum member 28 is arranged between a force point and a working point of the rocker arm to make a fulcrum of the rocker arm 26. A valve lift quantity of the suction valve 11 is varied by rotating the supporting member 28. Further, two suction cams 17, 18 having different cam profiles for each of cylinders are provided, and two pressure rollers 58, 59 corresponding to the cylinders are also provided. One of the rollers is selectively inserted between one of the two suction cams 17, 18 and the force point of the rocker arm 26 by a second actuator 62. By this arrangement, the rocker arm 26 is driven along a cam profile of only a selected suction cum to lift the suction valve 11.

with each other, and said second rocker shaft is pivotable around a center axis of said first rocker shaft for displacing said second rocker shaft.

[0019] Preferably, the first rocker arm has an curved contacting surface in contact with the second rocker arm. Said contacting surface of the first rocker arm is arcuate in shape with its center on a center axis of the camshaft.

[0020] According to a preferred embodiment at least one camshaft of said engine is provided with a variable valve timing device.

[0021] Other preferred embodiments of the present invention are laid down in further dependent claims.

[0022] In the following, the present invention is explained in greater detail with respect to several embodiments thereof in conjunction with the accompanying drawings, wherein:

FIG. 1 shows a vertical section of the cylinder head portion of a four-stroke cycle engine provided with an embodiment of the valve drive device;

FIG. 2 is a partial plan view of the valve drive device shown in FIG. 1;

FIG. 3 is a perspective view of an essential part of the valve drive device of the embodiment;

FIG. 4 is a partial cross-sectional view for explaining the operating principle of the valve drive device on the intake side;

FIG. 5 shows a graph of the extreme variations possible in valve lift and valve timing regarding the crank angle available by the valve drive device according to the embodiment;

FIG. 6 shows a graph of the possible variations and adjustments of valve lift and valve timing with regard to the crank angle and one direction of camshaft rotation; and

FIG. 7 shows a graph in part similar to FIG. 6 of the possible variations and adjustments in valve lift and valve timing with regard to the crank angle and the direction of camshaft rotation opposite to the direction of camshaft rotation of FIG. 6.

[0023] An embodiment of the invention will be hereinafter described in reference to the appended figures.

[0024] FIG. 1 shows a vertical section of the cylinder head portion of a four-stroke cycle engine provided with a valve drive mechanism of the embodiment. FIG. 2 is a partial plan view of the same engine. FIG. 3 is a perspective view of an essential part of the valve drive mechanism of the embodiment.

[0025] The four-stroke cycle engine 1 shown in FIGs. 1 and 2 is of the multi-cylinder type. Although not shown, a plural number of cylinders are arranged in the cylinder block of the engine 1 side by side in a row in the direction perpendicular to the drawing surface of FIG. 1 or lateral direction in FIG. 2, and a piston is slidably inserted in each cylinder. Each piston is connected through a connecting rod to a crankshaft.

[0026] A cylinder head 2 is placed on the cylinder block. As shown in FIG. 1, the cylinder head 2 is provided with two intake passages 3 (only one is shown) and two exhaust passages 4 (only one is shown) for each cylinder. Intake ports 3a and exhaust ports 4a where the intake and exhaust passages 3 and 4 open to a combustion chamber 5 are opened and closed with intake valves 6 and exhaust valves 7 driven with valve drive mechanisms 20 and 40 (valve drive devices) of the embodiment according to appropriate timing to exchange gasses as required in each cylinder.

[0027] The four-stroke cycle engine 1 of this embodiment is of the four-valve type with the intake and exhaust valves 6 and 7, two for each, for each cylinder. As shown in FIG. 1, the intake and exhaust valves 6 and 7 are slidably inserted in valve guides 8 and 9 press-fit in the cylinder head 2, and respectively forced toward the closing side with valve springs 12 and 13 interposed in compressed state between valve retainers 10, 11 and the cylinder head 2.

[0028] As shown in FIG. 2, an intake camshaft 14 and an exhaust camshaft 15, parallel to each other, are disposed in the crankshaft direction and rotatably supported in the upper part of the cylinder head 2. Chain sprockets 16 and 17 are attached to the ends, extending from one end surface of the cylinder head 2, on one side of the intake and exhaust camshafts 14 and 15. FIG. 2 also shows a plug hole 18 bored between the intake and exhaust camshafts 14 and 15 for each cylinder. An ignition plug (not shown) is screwed into the plug hole 18.

[0029] While the intake and exhaust valves 6 and 7 are driven with the valve drive mechanisms 20 and 40 of the embodiment, the valve drive mechanism 20 on the intake side for driving the intake valve 6 will be described in detail below.

[0030] The valve drive mechanism 20 on the intake side comprises rocker arms 21 and 22 arranged in upper and lower tiers. As shown in FIGs. 2 and 3, a pair of lower rocker arms 22 (first rocker arm) are provided right and left corresponding to the two intake valves 6 with the base ends of the lower rocker arms 22 interconnected through a boss portion 23. The lower rocker arms 22 are supported for up and down swing with a rocker shaft (rocking shaft) 24 passing through the boss portion 23. The underside of the distal end of each rocker arm 22 is in contact with the top of the valve stem of each intake valve 6, while the upper side of the distal end of each rocker arm 22 is formed as an arcuate surface with its center on the axis of the intake camshaft 14.

[0031] The rocker shaft 24 (first rocker shaft) is rotatably supported with the cylinder head 2. One end of the rocker shaft 24 is connected to a drive motor 25 (drive

means) attached to one end surface of the cylinder head 2. The drive motor 25 is a servomotor or a stepping motor that makes highly accurate control possible.

[0032] The upper rocker arm 21 (second rocker arm) on the other hand comprises as shown in FIGs. 2 and 3; a pair of rocker arm portions 26, a roller shaft 27 bridging the distal ends of the paired rocker arm portions 26, and a hollow cylindrical roller 28 supported for free sliding as penetrated with the middle part of the roller shaft 27. The outside circumferential surface of the roller 28 is in contact with the outside circumferential surface (cam surface) of an intake cam 14a formed integrally with the intake camshaft 14 for each cylinder. Right and left parts of the roller shaft 27 extending to be exposed out of the roller 28 are in contact with the arcuate surfaces F formed on the top surfaces of the rocker arms 22.

[0033] As described above, the rocker shaft 24 penetrates and rotatably supports the boss portion 23 of the rocker arm 22. Boss portions 29a of the paired right and left arms 29 (arm means) are secured to the rocker shaft 24 in positions on both sides of the boss portion 23. Therefore, while each arm 29 rotates together with the rocker shaft 24 about the axis of the rocker shaft 24, the base end portion of the rocker arm portion 26 of each rocker arm 21 is rotatably connected through a second rocker shaft (rocking shaft) 30 to the distal end of the arm 29. Therefore, the rocker arm portions 26 and 29 constitute a link mechanism of a V shape turned sideways as seen in side view, and the one rocker shaft (rocking shaft of the rocker arm 21) 30 provided at the connecting point of both of the arms 26, 29 is displaceable about the center of the other rocker shaft 24 (rocking shaft of the rocker arm 22).

[0034] As can be taken from FIGs. 2 and 3, said pair of rocker arm portions 26 of the second rocker arm 21 are spaced from each other and bridged by the roller shaft 27. The pair of arm means 29 are also spaced from each other and each of said arm means 29 is attached to the first rocker shaft 24. The arm means 29 and the associated rocker arm portion 26 are linked by a shaft section of the second rocker shaft 30, respectively. Said V-shaped linked mechanism constituted by the rocker arm portion 26, the arm means 29 and the rocker shaft 30 is symmetrically provided with regard to a plan perpendicular to the rotational axis of the camshaft 14 and passing between the pair of valves 6. Between said pair of arm means 29 and said pair of rocker arm portions 26 a free space is provided which allows at least the tip end section of the cam 14a of the camshaft 14 to rotate within.

[0035] Furthermore, as can be taken from FIGs. 2 and 3, the camshaft 14, the first and second rocker shafts 24, 30, the roller shaft 27 and the roller 28 are provided parallel with each other.

[0036] Since the constitution of the valve drive mechanism 40 on the exhaust side for driving the exhaust valve 7 is the same as that of the valve drive mechanism 20 on the intake side, detailed description of the former is omitted here. The valve drive mechanism 40 likewise comprises rocker arms 41 and 42 located in upper and lower tiers respectively, an arm 49, and a drive motor 45. The exhaust camshaft 15 has exhaust cams 15a formed integrally with the exhaust camshaft 15 for respective cylinders.

[0037] When the four-stroke cycle engine 1 is started and its crankshaft (not shown) is driven to rotate, the rotation is transmitted through a cam chain (not shown) and the chain sprockets 16 and 17 (See FIG. 2) to the intake and exhaust camshafts 14 and 15. The intake and exhaust camshafts 14 and 15 rotate at a half speed of the crankshaft. As a result, the valve drive mechanisms 20 and 40 drive the intake and exhaust valves 6 and 7 respectively to open and close the intake and exhaust ports 3a and 4a (See FIG. 1) according to appropriate timing.

[0038] When the intake camshaft 14 is driven to rotation as described above, the rocker arm 21 provided with the roller 28 in contact with the outside circumferential (cam) surface of the intake cam 14a swings up and down about the center of the rocker shaft 30 while the roller 28 is moved by the shape (profile) of the intake cam 14a. As the rocker arm 21 swings up and down, the rocker arm 22 in contact with the roller shaft 27 of the rocker arm 21 swings up and down about the rocker shaft 24. The swing of the rocker arm 22 drives the intake valve 6 to open and close the intake port 3a according to appropriate timing.

[0039] In other words, the lift of the intake cam 14a is transmitted from the roller 28 of the rocker arm 21 through the roller shaft 27 to the rocker arm 22, and further from the rocker arm 22 to the intake valve 6 to be pressed down, so that the intake port 3a is opened.

[0040] Likewise, the exhaust valve 7 is driven with the valve drive mechanism 40 to open and close the exhaust port 4a according to appropriate timing.

[0041] With the valve drive mechanisms 20 and 40 of the embodiment, the lift amount and opening-closing timing of the intake and exhaust valves 6 and 7 may be changed continuously. Here, the operating principle of the valve drive mechanism 20 on the intake side will be described in reference to FIGs. from 4 to 7. Since the operating principle of the valve drive mechanism 40 on the exhaust side is the same as that on the intake side, its description is omitted here.

[0042] FIG. 4 is a partial cross-sectional view for explaining the operating principle of the valve drive mechanism 20 on the intake side. FIGs. from 5 to 7 show how the lift amount and the opening-closing timing of the intake valve 7 change with the crank angle.

[0043] Assuming the reference position of the rocker shaft 30 (with its center on an axis Q) of the rocker arm 21 as shown with the solid line in FIG. 4, the roller 28 of the rocker arm 21 at this time is also in the position shown with the solid line, and the roller 27 is in contact with the point S on the arcuate surface F of the rocker

arm 22. The valve lift amount and the opening-closing timing of the intake valve 6 in this reference state with respect to the crank angle are shown in FIG. 5 with the curve (a).

[0044] When the rocker shaft 24 (with the axis R fixed) is rotated clockwise in FIG. 4 from the reference position by means of the drive motor 25 by a certain angle, the arm 29 connected to the rocker shaft 24 is also rotated by the same angle in the same direction. As a result, the rocker shaft 30 rotates about the rocker shaft 24, and comes to the position shown with the dash-and-double-dotted line (phantom line) in FIG. 4 (the axis of the rocker shaft 30 in this position is assumed to be Q'), the roller shaft 27 and the roller 28 move along the arcuate surface F to the position shown with the phantom line in FIG. 4. In this way, the contact point S of the roller shaft 27 with the arcuate surface F of the rocker arm 22 moves to the point S'.

[0045] When the roller 28 and the roller shaft 27 move from the solid line position to the phantom line position in FIG. 4, the length L2 of the line segment S'R, the length of lever, of the rocker arm 22 becomes longer than the length L1 of the line segment SR in the reference state (L2 > L1). As a result, the lift amount of the intake valve 6 (displacement amount of the contact point P of the rocker arm 22 with the intake valve 6) for the same lift amount of the intake cam 14a becomes smaller.

[0046] When the rotating direction of the intake cam 14 is as shown with the arrow R in FIG. 4, the roller 28 shown with the phantom line is in an earlier position than that shown with the solid line with respect to the rotating direction of the intake camshaft 14, and the opening-closing timing of the intake valve is advanced. By contrast, when the rotating direction of the intake cam 14 is as shown with the arrow L in FIG. 4, the roller 28 shown with the phantom line is in a later position than that shown with the solid line with respect to the rotating direction of the intake camshaft 14, and the opening-closing timing of the intake valve is delayed.

[0047] Therefore, the lift amount and the opening-closing timing of the intake valve 6 in the state of the roller 28 and the roller shaft 27 having moved from the solid line position to the phantom line position in FIG. 4 and the intake camshaft 14 rotating in the direction R are shown with the curve (b) in FIG. 5 with respect to the crank angle. When the intake camshaft 14 rotates in the direction L, the lift amount and the opening-closing timing of the intake valve 6 are shown with the curve (c) in FIG. 5 with respect to the crank angle.

[0048] Therefore, the lift amount and the opening-closing timing of the intake valve 6 can be changed continuously by moving the roller shaft 27 and the roller 28 along the arcuate surface F of the rocker arm 22 by driving the rocker shaft 24 with the drive motor 25.

[0049] FIGs. 6 and 7 show the lift amount and the opening-closing timing of the intake valve 6 when the intake camshaft rotates in the direction of R and L respectively when the roller shaft 27 and the roller 28 are moved along the arcuate surface F of the rocker arm 22 as the rocker shaft 24 is driven with the drive motor 25 by angles θ (∠SRQ in FIG. 4) of 20, 30, 40, 50, and 60 degrees respectively.

[0050] As shown in FIGs. 6 and 7, the lift amount of the intake valve 6 increases with the increase in the angle θ (namely with the clockwise movement of the roller 28 about the axis C of the intake camshaft 14) irrespective of the rotating direction of the intake camshaft 14.

[0051] When the intake camshaft 14 rotates in the direction R, the opening-closing timing of the intake valve 6 is delayed with the increase in the angle θ as shown in FIG. 6, and when the intake camshaft 14 rotates in the direction L, the opening-closing timing of the intake valve 6 is advanced with the increase in the angle θ as shown in FIG. 7.

[0052] As described above, this embodiment is arranged that the lift amount and opening-closing timing of the intake valve 6 (exhaust valve 7) are continuously changed by moving the roller 28 by displacing the rocker shaft 30 of the rocker arm 21, one of the rocker arms 21 and 22. Therefore, unlike with the conventional variable valve lift mechanism, this embodiment makes it unnecessary to employ a plural number of cams and switching means for every cylinder, to employ a variable valve timing device requiring complicated mechanism and control, and makes it possible to achieve an optimum engine performance with a simple constitution. In particular, the possibility of continuously changing the valve lift amount enables setting the valve lift amount commensurate with the intake amount to enable improvement in the engine output while reducing the lost power associated with the valve drive train.

[0053] During the movement of the valve drive mechanism 20, since the contact point of the roller shaft 27 with the arcuate curved surface F of the rocker arm 22 constantly moves as the rocker arm 22 swings, wear between the two components is restrained.

[0054] Moreover, if variable timing devices 50 and 60 are provided at the ends of the intake and exhaust camshafts 14 and 15 as shown with phantom lines in FIGs. 1 and 2, it is possible to change only the valve lift amount by offsetting the change in the opening-closing timing of the intake and exhaust valves 6 and 7, or it is possible to increase the range of change in the valve timing.

[0055] Furthermore, according to the embodiment, the valve drive mechanism 20 (40) uses the driving motor 25 (45) such as a servomotor or stepping motor that can be controlled easily to displace the rocker shaft 30 of the rocker arm 21 by rotating the rocker shaft 24 of the rocker arm 22 with the drive motor 25 (45), and to move the roller 28. As a result, constitution of the valve drive mechanism 20 (40) is simplified to reduce cost and to enable high accuracy control.

[0056] Furthermore, the valve drive mechanism 20 (40) of this embodiment can be made free from rattle as the surface F of the rocker arm 22 in contact with the

roller shaft 27 is made arcuate about the axis of the camshaft 14 so that a certain gap is always present between the outside circumferential surface of the roller 28 and the camshaft base circle shown with a phantom line C' in FIG. 4 when the roller shaft 27 moves along the arcuate surface F.

[0057] While the above description of this embodiment is made that the rocking shaft (rocker shaft) of only one of the rocker arms is made displaceable, the same effect is provided even if the rocker shafts of both of the rocker arms are made displaceable.

[0058] As is clear from the above description, this embodiment relates to a valve drive mechanism for four-stroke cycle engines with valves opened and closed by the lift of rotation-driven cams transmitted through rocker arms to the valves. The rocker arms of the valve drive mechanism are arranged in two tiers to rock while contacting each other. Since at least one rocker shaft of the rocker arm is made displaceable, the valve lift amount and the valve opening-closing timing can be changed continuously to achieve an optimum engine performance.

[0059] Although the embodiment as shown teaches a valve drive device of an in-line multi-cylinder engine, said valve drive device can be easily adapted to a single cylinder engine. Furthermore, the valve drive device according to the above-mentioned embodiment can be also adapted to a V-type engine or the like.

[0060] The above-mentioned embodiment teaches a multi-valve engine, in particular a four-valve engine provided with said valve drive device. However, said valve drive device can be also adapted to a two-valve type engine with a single intake valve and a single exhaust valve for each cylinder. In this case, the first and second rocker arms are formed with respective single rocker arm portions wherein the respective cam is acting directly on the respective single arm portion of the second rocker arm or a roller means is directly provided at said single arm portion of the second rocker arm.

[0061] Furthermore, the above-mentioned embodiment shows a valve drive device with the first and second rocker arms for an intake side of the cylinder and a valve drive device with a first and second rocker arm for the exhaust side of the cylinder. However, the valve drive device with the first and second rocker arms as mentioned above can be also used on one of said intake or exhaust side of the respective cylinder while the respective other side is provided with a conventional valve drive mechanism. Moreover, the valve drive device with the first and second rocker arms as mentioned above can be also used with a single camshaft for the intake and exhaust sides of the cylinder. In this case, the valve drive device with the first and second rocker arms is used for one side and the respective valves with regard to the respective cams while on same camshaft the cams for the opposing side are also provided and the swinging arms as well known in the art are used for acting the valve of the opposing sides.

[0062] Accordingly, the above-mentioned embodiment shows a valve drive device of an internal combustion engine in particular a four-stroke cycle engine, for operating at least one of intake and/or exhaust valves 6,7 by at least one cam shaft 14,15, with a rocker arm unit for transmitting a controlling movement to said valve 6,7, said rocker arm unit comprises first and second rocker arms 21,22,41,42 supported on first and second rocker shafts 24,30, respectively. Said first and second rocker arms 21,22,41,42 are in mutual contact and at least one of the rocker shafts 30 is displaceable.

[0063] Said embodiment also shows a valve drive device of an internal combustion engine in particular a four-stroke cycle engine, for operating at least one of intake and/or exhaust valves 6,7 by a rotating cam 14a,15a associated with said valve 6,7. A rocker arm unit is interposed between said cam 14a,15a and said valve 6,7 for transmitting a controlling movement to said valve 6,7 and for adjusting both a degree of lift and a lift curve of said valve 6,7 so as to change the a timing and lift operation of said valve.

[0064] The Valve drive device of said embodiment is constituted in that, the first rocker shaft 24 is fixed and the first rocker arm 22,42 supported on the said first rocker shaft 24 is in contact with said valve 6,7, and the second rocker shaft 30 is displaceable and the second rocker arm 21,41 supported on the said second rocker shaft 30 is in contact with a cam 14a,15a of the cam shaft 14,15 and with the first rocker arm 22,42. A contact point S,S' of the first rocker arm 22,42 with the second rocker arm 21,41 is moveable on the first rocker arm 22,42 in accordance with the displacement of the second rocker shaft 30.

[0065] An arm means 29,49 is attached to the first rocker shaft 24, and the second rocker shaft 30 is supported at said arm means 29,49. Said arm means 29,49 is pivotably about the first rocker shaft 24, wherein a drive means 25,45 is provided for pivoting said arm means 29,49. A pivoting angle Θ of the arm means 29,49 is controllable by a controlling unit in accordance with engine operating conditions.

[0066] The second rocker arm 21,41 comprises a roller 28. Said roller 28 is rotatable and in contact with the cam 14a,15a of the cam shaft 14,15. Said roller 28 is rotatably supported on a roller shaft 27, and said roller shaft 27 is in contact with the first rocker arm 22,42.

[0067] In the embodiment of the valve drive device the second rocker arm 21,41 comprises a pair of rocker arm portions 26 spaced from each other and bridged by a roller shaft 27 at distal ends thereof. Said first rocker arm 22,42 comprises a pair of rocker arm portions being in contact with a pair of valves 6,7, respectively. Said roller 28 is provided between the rocker arm portions of the first rocker arm 22,42 and rotatably supported on the roller shaft 27. Parts of the roller shaft 27 are exposed out of the roller 28 and in contact with the rocker arm portions of the first rocker arm 22,42.

[0068] According to the preferred embodiment a pair

of arm means 29,49 spaced from each other is attached to the first rocker shaft 24. The second rocker shaft 30 comprises a pair of shaft sections supported at said pair of arm means 29,49, respectively. Said pair of shaft sections of the second rocker shaft 30 supporting the pair of rocker arm portions 26, respectively. A free space is provided between said pair of arm means 29,49 and the pair of rocker arm portions 26 to allow the cam 14a,15a of the cam shaft 14,15 to rotate within said free space. The rocker arm portions of the first rocker arm 22,42 are connected by a boss portion 23 rotatably supported on said first rocker shaft (24).

[0069] As clearly visible from the figures of the embodiment, said first rocker shaft 24 and said second rocker shaft 30 are parallel with each other, and said second rocker shaft 30 is pivotable around a center axis of said first rocker shaft 24 for displacing said second rocker shaft 30.

[0070] According to the preferred embodiment, the first rocker arm 22,42 has an curved contacting surface F in contact with the second rocker arm 21,41.Said contacting surface F of the first rocker arm 22,42 is arcuate in shape with its center on a center axis of the camshaft 14,15.

[0071] According to the preferred embodiment, at least one camshaft 14,15 of said engine is provided with a variable valve timing device 50,60. Said engine is a multi valve engine in particular a four valve engine.

[0072] The above mentioned embodiment shows a valve drive mechanism of a four-stroke cycle engine wherein valves are opened and closed as the lifts of cams formed on a rotary-driven camshaft are transmitted through rocker arm units to the valves, and each rocker arm unit is constituted with two rocker arms that rock in mutual contact, and the rocking shaft of at least one rocker arm is made displaceable so that the valve lift amount and opening-closing timing are continuously variable.

[0073] Furthermore the rocking shaft of the first rocker arm is fixed and the first rocker arm is made to contact a valve, the second rocker arm with displaceable rocking shaft is made to rotatably support a roller through a roller shaft, the roller is made to contact the cam, and the roller shaft is made to contact the first rocker arm.

[0074] Since the valve lift amount and the valve opening-closing timing are made continuously variable by making at least one of the rocking shafts of the two tiers of rocker arms displaceable, it is unnecessary to provide a plural number of cams and switching means for every cylinder and to provide a variable valve timing device of complicated constitution and control. As a result, an optimum engine performance is achieved with a simple constitution.

[0075] One end of an arm is attached to the rocking shaft of the first rocker arm, and one end of the second rocker arm is supported with a rocking shaft freely rotatably at the other end of the arm. The arm is rotated about the rocking shaft of the first rocker arm as the rocking shaft is driven with a drive means, so that the rocking shaft of the second rocker arm is displaced.

[0076] Since the rocking shaft of the second rocker arm is made displaceable by rotating the rocking shaft of the first rocker arm with a drive means such as a stepping motor or a servomotor operable by simple control, the constitution of the valve drive mechanism is simplified, its cost is lowered, and high accuracy control is made possible.

[0077] The roller shaft contacting surface of the first rocker arm is made an arcuate surface with its center on the camshaft. Preferably, the camshaft is provided with a variable valve timing device.

[0078] Since the surface of the first rocker arm to be contacted with the roller shaft is made an arcuate surface with its center on the camshaft axis, a constant gap is present between the outside circumferential surface of the roller and the camshaft base circle when the roller moves along the arcuate surface.

[0079] Moreover, it is possible with the variable valve timing device to change only the valve lift amount by offsetting the change in the valve opening-closing timing or to increase the range of change in the valve timing.

[0080] The above mentioned embodiment provides a valve drive mechanism capable of achieving an optimum engine performance by continuously changing lift amount and opening-closing timing of valves with a simple constitution.

[0081] In said valve drive mechanism 20 of a four-stroke cycle engine wherein a valve 6 is opened and closed as the lift of a cam 14a formed on a rotary-driven camshaft 14 is transmitted through a rocker arm unit to the valves, the rocker arm unit is constituted with two tiers of rocker arms 21 and 22 that rock in mutual contact. And a rocking (rocker) shaft 30 of at least one rocker arm 21 is made displaceable so that lift amount and opening-closing timing of the valve 6 are continuously variable.

[0082] Since the lift amount and opening-closing timing of the valve 6 are made continuously variable by displacing the rocker shaft 30 of at least one (21) of the two tiers of rocker arms 21 and 22, it is unnecessary to employ a plural number of cams and switching means, and variable valve timing devices requiring complicated control. As a result, optimum engine performance is achieved with a simple constitution.

Claims

1. Valve drive device of an internal combustion engine in particular a four-stroke cycle engine, for operating at least one of intake and/or exhaust valves (6,7) by at least one cam shaft (14,15), with a rocker arm unit for transmitting a controlling movement to said valve (6,7), said rocker arm unit comprises first and second rocker arms (21,22,41,42) supported on first and second rocker shafts (24,30), respectively,

wherein said first and second rocker arms (21,22,41,42) are in mutual contact and at least one of the rocker shafts (30) is displaceable.

2. Valve drive device of an internal combustion engine in particular a four-stroke cycle engine, for operating at least one of intake and/or exhaust valves (6,7) by a rotating cam (14a,15a) associated with said valve (6,7), with a rocker arm unit interposed between said cam (14a,15a) and said valve (6,7) for transmitting a controlling movement to said valve (6,7) and for adjusting both a degree of lift and a lift curve of said valve (6,7) so as to change the a timing and lift operation of said valve.

3. Valve drive device of an internal combustion engine according to claim 2, **characterized in that** said rocker arm unit comprises first and second rocker arms (21,22,41,42) supported on first and second rocker shafts (24,30), respectively, wherein said first and second rocker arms (21,22,41,42) are in mutual contact and at least one of the rocker shafts (30) is displaceable.

4. Valve drive device of an internal combustion engine according to claim 1 or 3, **characterized in that** the first rocker shaft (24) is fixed and the first rocker arm (22,42) supported on the said first rocker shaft (24) is in contact with said valve (6,7), and the second rocker shaft (30) is displaceable and the second rocker arm (21,41) supported on the said second rocker shaft (30) is in contact with a cam (14a,15a) of the cam shaft (14,15) and with the first rocker arm (22,42), wherein a contact point (S,S') of the first rocker arm (22,42) with the second rocker arm (21,41) is moveable on the first rocker arm (22,42) in accordance with the displacement of the second rocker shaft (30).

5. Valve drive device of an internal combustion engine according to claim 4, **characterized in that** an arm means (29,49) is attached to the first rocker shaft (24), and the second rocker shaft (30) is supported at said arm means (29,49).

6. Valve drive device of an internal combustion engine according to claim 5, **characterized in that** the arm means (29,49) is pivotably about the first rocker shaft (24), wherein a drive means (25,45) is provided for pivoting said arm means (29,49).

7. Valve drive device of an internal combustion engine according to claim 6, **characterized in that** a pivoting angle (Θ) of the arm means (29,49) is controllable by a controlling unit in accordance with engine operating conditions.

8. Valve drive device of an internal combustion engine according to at least one of the claims 4 to 7, **characterized in that** the second rocker arm (21,41) comprises a roller (28), said roller (28) is rotatable and in contact with the cam (14a,15a) of the cam shaft (14,15).

9. Valve drive device of an internal combustion engine according claim 8, **characterized in that** said roller (28) is rotatably supported on a roller shaft (27), and said roller shaft (27) is in contact with the first rocker arm (22,42).

10. Valve drive device of an internal combustion engine according to at least one of the claims 4 to 7, **characterized in that** the second rocker arm (21,41) comprises a pair of rocker arm portions (26) spaced from each other and bridged by a roller shaft (27) at distal ends thereof, and said first rocker arm (22,42) comprises a pair of rocker arm portions being in contact with a pair of valves (6,7), respectively.

11. Valve drive device of an internal combustion engine according to claim 10, **characterized in that** a roller (28) is provided between the rocker arm portions of the first rocker arm (22,42) and rotatably supported on the roller shaft (27), wherein parts of the roller shaft (27) are exposed out of the roller (28) and in contact with the rocker arm portions of the first rocker arm (22,42).

12. Valve drive device of an internal combustion engine according to claim 10 or 11, **characterized in that** the rocker arm portions of the first rocker arm (22,42) are connected by a boss portion (23) rotatably supported on said first rocker shaft (24).

13. Valve drive device of an internal combustion engine according to at least one of the claims 10 to 12, **characterized in that** a pair of arm means (29,49) spaced from each other is attached to the first rocker shaft (24), and the second rocker shaft (30) comprises a pair of shaft sections supported at said pair of arm means (29,49), respectively, said pair of shaft sections of the second rocker shaft (30) supporting the pair of rocker arm portions (26), respectively, wherein a free space is provided between said pair of arm means (29,49) and the pair of rocker arm portions (26) to allow the cam (14a,15a) of the cam shaft (14,15) to rotate within said free space.

14. Valve drive device of an internal combustion engine according to at least one of the claims 4 to 13, **characterized in that** said first rocker shaft (24) and said second rocker shaft (30) are parallel with each other, and said second rocker shaft (30) is pivotable around a center axis of said first rocker shaft (24) for displacing said second rocker shaft (30).

15. Valve drive device of an internal combustion engine according to at least one of the claims 4 to 14, **characterized in that** the first rocker arm (22,42) has an curved contacting surface (F) in contact with the second rocker arm (21,41).

16. Valve drive device of an internal combustion engine according to claim 15, **characterized in that** said contacting surface (F) of the first rocker arm (22,42) is arcuate in shape with its center on a center axis of the camshaft (14,15).

17. Valve drive device of an internal combustion engine according to at least one of the claims 1 to 16, **characterized in that** at least one camshaft (14,15) of said engine is provided with a variable valve timing device (50,60).

18. Valve drive device of an internal combustion engine according to at least one of the claims 1 to 17, **characterized in that** said engine is a multi valve engine in particular a four valve engine.

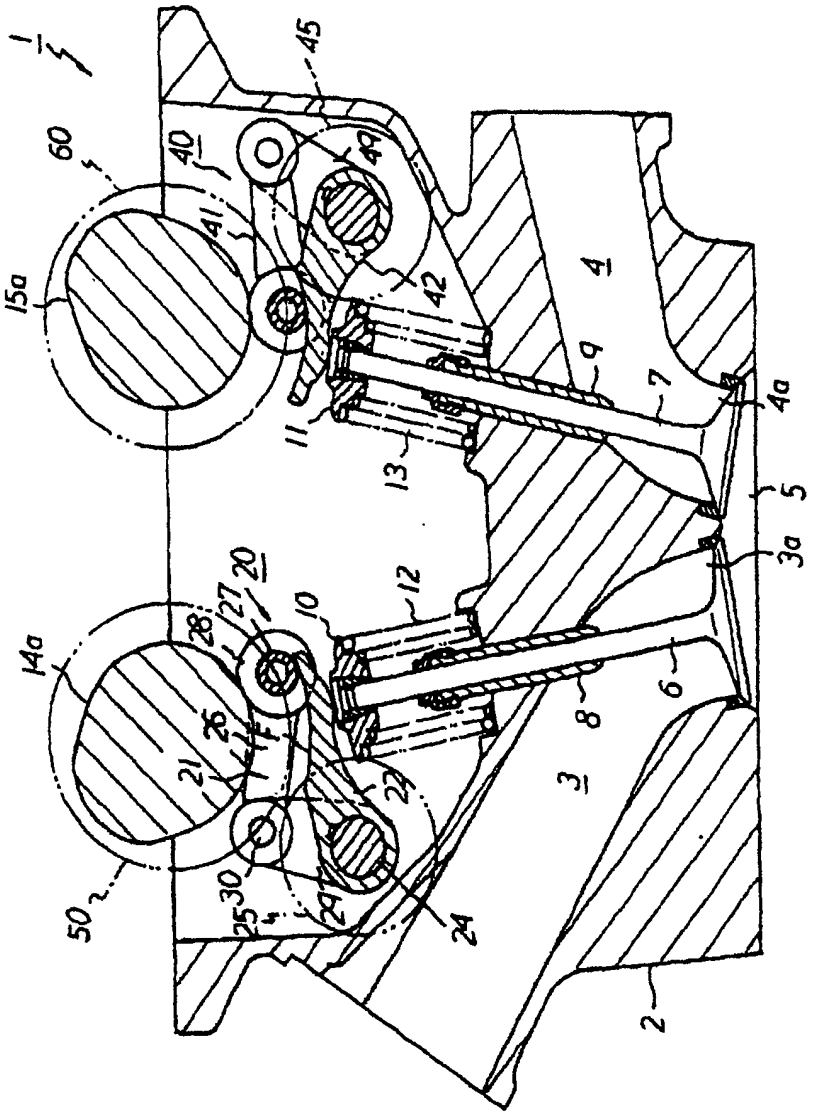

FIGURE 1

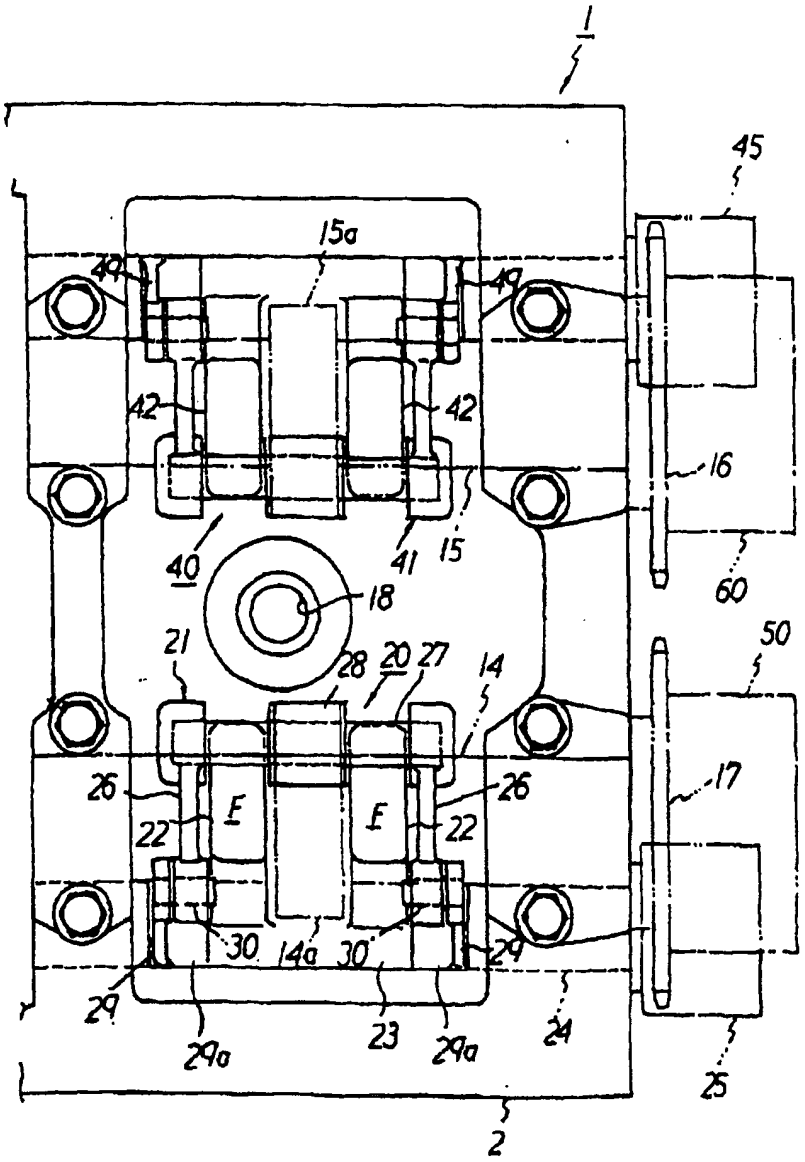

FIGURE 2

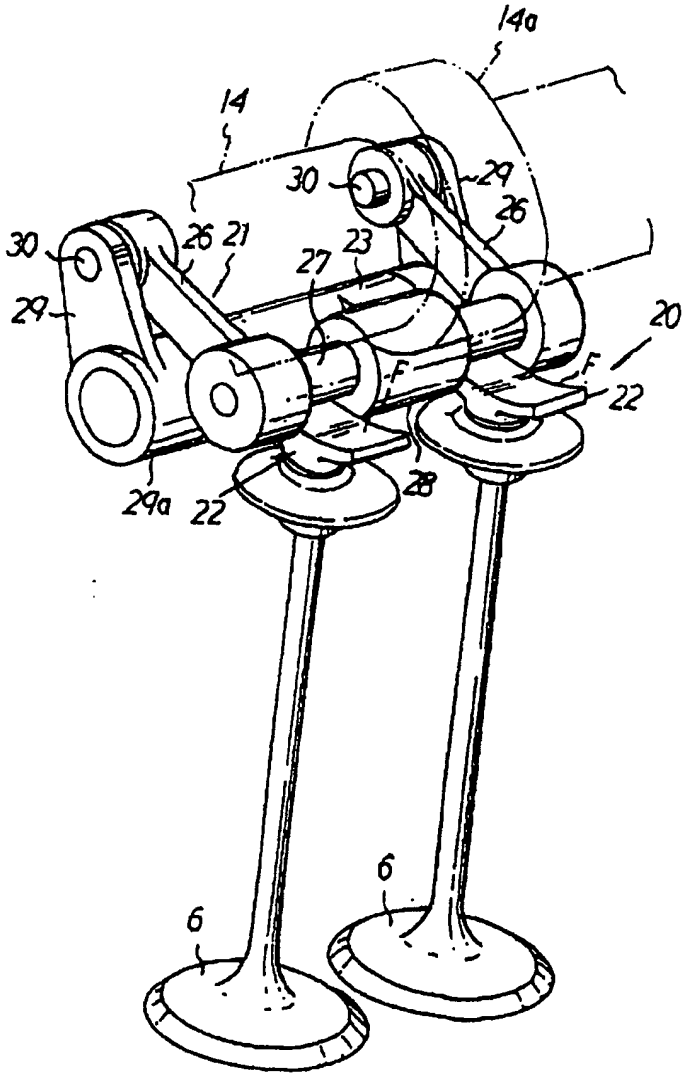

FIGURE 3

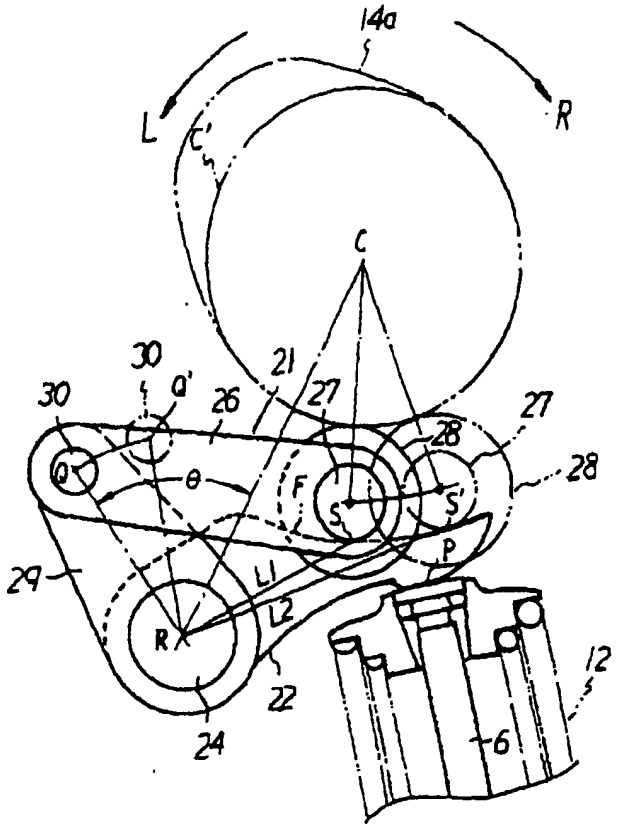

FIGURE 4

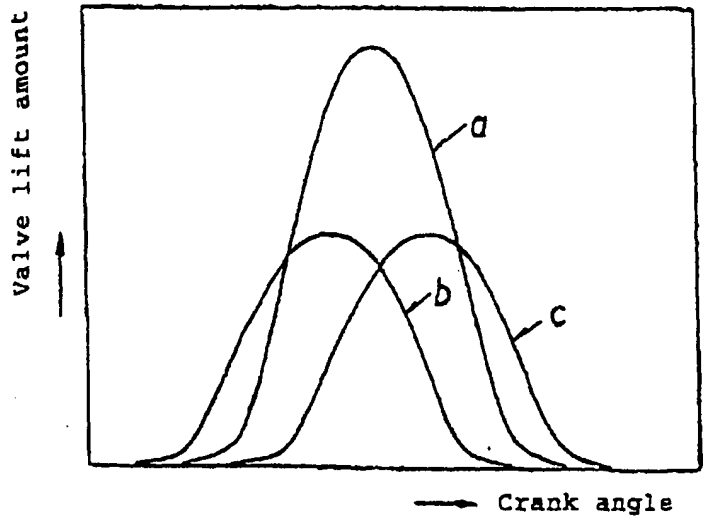

FIGURE 5

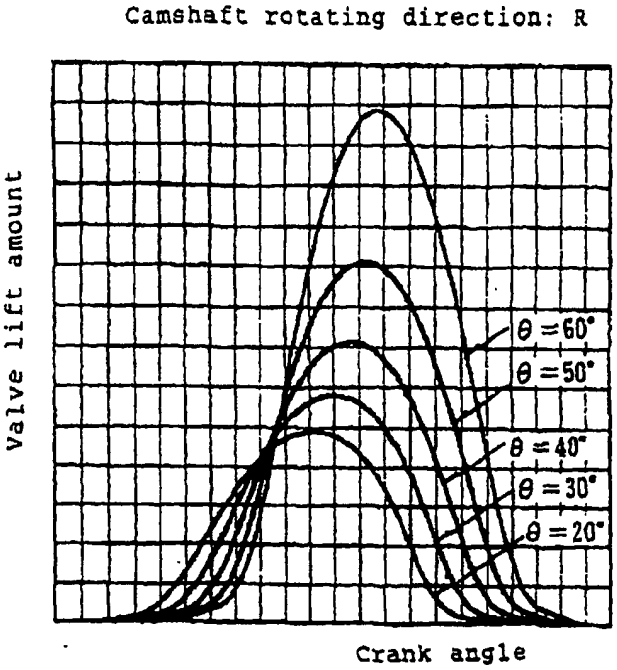

FIGURE 6

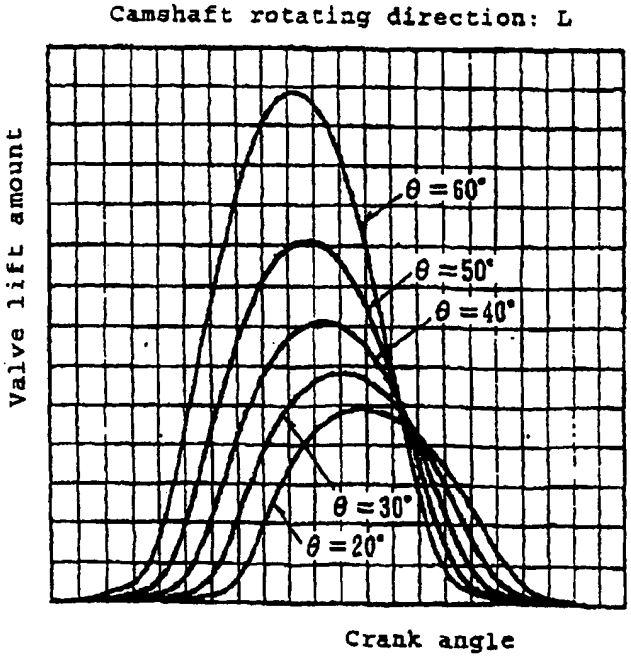

FIGURE 7